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Effects of new bus and rail rapid transit systems – an international review

ABSTRACT Cities worldwide are implementing modern transit systems to improve mobility in the increasingly congested metropolitan areas. Despite much research on the effects of such systems, a comparison of effects across transit modes and countries has not been studied comprehensively. This paper fills this gap in the literature by reviewing and comparing the effects obtained by 86 transit systems around the world including Bus Rapid Transit (BRT), Light Rail Transit (LRT), metro, and heavy-rail transit systems. The analysis is two-fold by analysing i) the direct operational effects related to travel time, ridership, and modal shifts, and ii) the indirect strategic effects in terms of effects on property values and urban development. The review confirms the existing literature suggesting that BRT can attract many passengers if travel time reductions are significantly high. This leads to attractive areas surrounding the transit line with increasing property values. Such effects are traditionally associated with attractive rail-based public transport systems. However, a statistical comparison of 41 systems did not show significant deviations between effects on property values resulting from BRT, LRT, and metro systems, respectively. Hence, this paper indicates that large strategic effects can be obtained by implementing BRT systems at a much lower cost.

Keywords: Bus Rapid Transit (BRT), Light Rail Transit (LRT), property values, traffic impacts, urban development, public transport systems, system comparison.

1 Introduction

Public transport systems are important for improving mobility and relieving traffic congestion in the increasingly congested metropolitan areas. Hence, cities around the world are searching for the most efficient way of upgrading their public transport networks. This involves planning the appropriate cost-effective system for a given context ranging from low-cost Bus Rapid Transit systems (BRT) over modern Light Rail Transit (LRT) to more costly, but highly attractive metro or urban railway systems. With the increasing focus on cost-effectiveness in transport investments it is important to know the possible effects when upgrading public transport networks. This reveals the strengths and weaknesses of various systems including the drivers for ensuring that the systems will be attractive for passengers.

Over the past decades BRT and LRT systems have experienced increased popularity due to their ability to deliver attractive service levels at a lower cost than those of heavy rail and metro systems. In Europe the first modern light rail system was opened in 1985 in Nantes. Due to the success of the system, several other French cities implemented light rail systems in the following years in corridors where the ridership was too small to justify an expensive metro solution, but where there was a wish to upgrade the existing bus operations (Bottoms, 2003). In Latin America several cities have focused on BRT systems, primarily due to the lower construction costs. The first systems were established in the 1970s and 1980s in the aftermath of the successful *Rede Integrada de*

Transporte in Curitiba, Brazil, which was established in 1974. The number of BRT systems has increased significantly, particularly within the last 10 years, and currently, 200 cities have BRT systems serving 33 million passengers every day, 88% of them located in Latin America or Asia (“Global BRT Data,” 2016). However, BRT systems are also becoming increasingly popular in Europe, where they are often also referred to as Buses with High Level of Service (BHLS) (Hidalgo & Muñoz, 2014). Hence, successful systems now exist in many European cities including Paris, Nantes, Rouen, Madrid, Amsterdam and many others (Finn et al., 2011).

The systems vary greatly between countries, especially for BRT which is not a strict definition. Much literature therefore focuses on the design concepts and system characteristics of BRT (Levinson, Zimmerman, Clinger, & Rutherford, 2002), (Wright & Hook, 2007), (Hensher & Golob, 2008), (Nikitas & Karlsson, 2015), (Wirasinghe et al., 2013), and others. Some studies investigate the individual attractiveness of such characteristics on ridership for BRT (Currie & Delbosc, 2011) and for LRT (Currie, Ahern, & Delbosc, 2011), while studies also exist that compare across the two modes (Currie & Delbosc, 2013). In addition, many single transit systems have been analysed in terms of effects on ridership, urban development and property values (Cao & Schonerr, 2014; Cervero, 1984; Dueker & Bianco, 1999; Knowles, 1996, and many others). These studies include a review of the relevant literature, but often focus on either BRT or LRT systems only.

A few papers review the urban development effects focusing on either BRT (Currie, 2006b; Stokenberga, 2014) or LRT systems (Knowles & Ferbrache, 2015). In (Ryan, 1999) the effects of property values are compared across the modes of light rail, heavy rail and highways while also focusing on methodological differences between studies throughout the 1960s-1990s. Several other studies compare the effects between BRT and metro in Beijing (Ma, Ye, & Titheridge, 2014) and Guangzhou (Salon, Wu, & Shewmake, 2014), and between BRT and LRT in Pittsburgh (V. Perk, Mugharbel, & Catalá, 2010). The limitations of these studies consist in them either focusing on the effects of a single public transport mode (Currie, 2006b; Knowles & Ferbrache, 2015; Stokenberga, 2014), not including the three main high-class public transport modes of metro, LRT and BRT (Ryan, 1999), and/or only reviewing a few studies (Ma et al., 2014; V. Perk et al., 2010; Salon et al., 2014).

This paper fills the gap in the literature by reviewing the effects of a large sample of 86 transit systems including BRT, LRT and metro/heavy rail. The effects have been analysed in terms of changes in demand, including modal shifts (section 2), and strategic effects in terms of changes in property values (section 3). Furthermore, section 4 presents a number of examples on the impacts on city development. Section 5 discusses the methodological considerations and points to future work while section 6 concludes the review by highlighting the impacts caused by the various public transport modes and thus compares the mode-dependent effects.

2 Traffic impacts

One of the main reasons for upgrading and extending public transport is to obtain travel time benefits for the users of the system. It is therefore essential to study the potential travel time improvements of metro, LRT and BRT, respectively. In urban areas the construction of a metro provides the biggest travel time benefits as metros run in fully segregated right-of-way as opposed to light rail systems and BRT which are often constructed at street level with crossings. High speeds with light rail systems and BRT can however be obtained by implementing dedicated right-of-way, signal priority, and other Advanced Public Transport Systems (APTS) elements (Ingvardson, Jensen, & Nielsen, 2015). The various elements of BRT make it easy to adapt the concept to a local context. However, this flexibility may lead to the implementation of half measures where one or often several elements have been left out to save construction costs (Rodríguez & Targa, 2004). As a consequence, big variations exist between the various systems around the world. Some systems are just conventional bus lines that have been upgraded with a few BRT elements, for instance bus lanes, signal priority or special vehicles. Other systems contain entire corridors with completely segregated bus lanes, station-like bus stops with ticketing systems on the platform, real-time information and signal priority along the entire corridor. Such large differences between system solutions make it difficult to establish general impacts as they will depend on the design of the system and the degree of improvement with respect to the original solution.

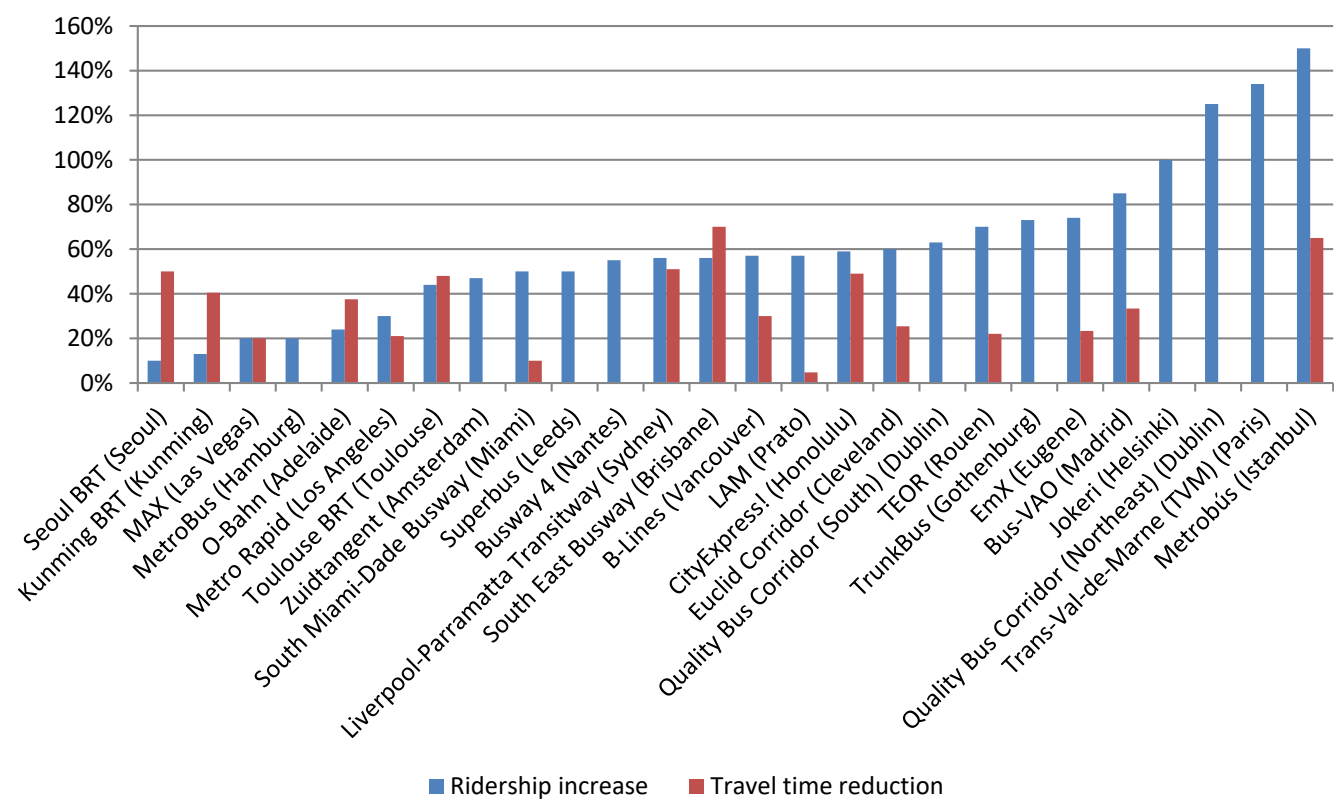


Figure 1: Relationship between travel time reductions and increase in ridership for selected BRT systems.

Figure 1 clearly shows the large variation in ridership effects of various BRT systems. Some of the largest increases in ridership were obtained by Metrobús in Istanbul, where a thorough implementation of BRT elements, including an almost fully segregated infrastructure, ensured travel time reductions of 65% resulting in 150% more passengers (Yazici, Levinson, Ilicali, Camkesen, &

Kamga, 2013). In Paris, the Trans-Val-de-Marne route was reported to gain an increase of 134% in ridership after opening; this increase however possibly included effects of general traffic growth as it was measured over a longer period of time. The system induced significant improvements to travel time in terms of 16 minutes decrease in travel time through the 20 km corridor (Finn et al., 2011). In Dublin, the implementation of Quality Bus Corridors resulted in significantly increased ridership of up to 125% for the northeastern Malahide corridor (Finn et al., 2011) and 63% for the southern Stillorgan corridor (O'Mahony, 2002). This despite the corridors not being full BRT systems as they mainly included bus lanes (shared with taxis and bicyclists) and some service improvements including higher frequency and bus priority. This resulted in significantly increased bus travel speeds and faster than car travel speeds during peak hours, however, primarily because of simultaneous closure of road traffic lanes (O'Mahony, 2002). In Madrid, the Bus-VAO system obtained a 33% travel time reduction due to its running almost fully segregated. Together with strong connections to the metro network ridership increased by 85% (Heddebaut, Finn, Rabuel, & Rambaud, 2010). Several systems were implemented in the United States with dedicated infrastructure and strong branding resulting in increased travel speed and ridership, e.g. the EmX BRT system in Eugene which attracted 74% more passengers by implementing off-board fare collection and dedicated busways. Combined with strong branding it resulted in a 23% travel time reduction. The Cleveland Euclid corridor BRT resulted in a 60% ridership increase after two years of operation due to a largely segregated system ensuring a 34% speed increase (Weinstock, Hook, Replogle, & Cruz, 2011). In Honolulu, a 49% travel time reduction resulted in a 59% ridership increase after one year of service (City and County of Honolulu, 2001). And in Miami, the South Miami-Dade Busway resulted in a 50% increase in ridership resulting from a travel time reduction of less than 10% (National BRT Institute, 2003). The system incorporated fully segregated busways and special stations equipped with information and shelters. In Europe, similar impacts were obtained in several cities, including Rouen, Prato and Nantes, which saw passenger ridership increases in the same ranges around 60%. In Prato, Italy, a relatively small improvement in travel time resulted in a big increase in ridership due to a simultaneous doubling of frequency and strong branding (Heddebaut et al., 2010). The systems in Nantes and Rouen both included almost full segregation, special branding and some pre-board fare collection resulting in high levels of reliability and ridership increases of 55-70%. Also in Australia several systems obtained large positive effects. In Brisbane, ridership increased by 56% due to a fully segregated system with signal priority and high frequency resulting in a 70% travel time reduction (Currie, 2006a). The Liverpool-Parramatta Transitway in Sydney implemented dedicated busways and bus lanes as well as Intelligent Transport Systems (ITS) elements including traffic signal priority, real time passenger information and some off-board fare collection (Currie, 2006a). The implementation ensured a 51% travel time reduction and 56% ridership increase.

In other places, only smaller effects were seen despite implementing thorough and high-class systems with travel time reductions of 40-50%. In Seoul, the effect of the BRT on ridership was only a 10% increase within one year after opening, which however should be compared to a general

decline in ridership for buses during the same period as well as a very high attractiveness of the Seoul subway carrying 35% of all trips in Seoul (Cervero & Kang, 2011). Hence, the public transport system was quite attractive already before implementing BRT. In Kunming, ridership increased by 13% at its opening, but an increase of 100% was seen five years after opening (Darido, 2006). The Las Vegas MAX bus line resulted in a 25% ridership increase when implementing segregation in 60% of the corridor, off-board fare collection and specially branded buses resulting in a travel time reduction of 20% (Weinstock et al., 2011). The Metro Rapid system in Los Angeles did not feature segregated infrastructure, but relied on efficient route design with longer stop spacings, signal priority, special branding of vehicles and stations that allowed for faster dwell times (Hoffman, 2008). The average travel time reductions of 21% resulted in increased ridership of 15-20%, for some corridors up to 33% (Levinson et al., 2002). In Hamburg, the Metrobus system improved the existing bus line by implementing segregation on 27% of the corridor, some branding, strong integration and signal priority resulting in minor increases to travel speed and ridership (Finn et al., 2011).

These results show that all systems had notable effects on travel time and thus ridership. Systems that included thorough implementations of many BRT elements such as dedicated bus lanes on most segments, signal priority, pre-board fare collection and special branding obtained significant improvements of travel time and ridership. When combined, these elements can notably improve not only travel times, but also reliability which is often difficult to improve in bus operations, hence causing bus bunching, e.g. in Gothenburg (Heddebaut et al., 2010) and Copenhagen (Ingvardson et al., 2015). The results however also show that effects vary notably between systems and cannot only be explained by travel time improvements. Several other factors influence the effects such as the attractiveness of the existing public transport network and the car traffic conditions, including road congestion and car use restrictions. But also factors related to the local context seem to play a role which has not been fully investigated in the reviewed studies. Hence, there seems to be a knowledge gap regarding the influence and importance of factors not related to the actual improvement of the public transport line which may explain the attractiveness of the public transport line.

2.1 Modal shift

The increased ridership when implementing new public transport systems is caused by both induced traffic and a mode shift effect. In several places it has thus been observed that the new system has attracted users who previously used other modes, e.g. cars. Mode shifts from cars are especially important for two major reasons. Firstly, shifting car users to public transport will relieve congestion in the often very congested road network in large metropolitan areas. Secondly, there is an increasing focus by policy makers to promote sustainable transport for environmental reasons. In Table 1 the mode shift from cars is listed for a range of public transport systems. The systems mentioned gave rise to significant mode shifts from other modes, especially from buses, e.g. in Copenhagen and

Istanbul (Vuk, 2005; Yazici et al., 2013), from bicycles in Utrecht (Finn et al., 2011) and from metro in Stockholm (Finn et al., 2011).

System	Mode shift ¹	Source
Metrobús (BRT, Istanbul)	4-9%	(Yazici et al., 2013) (Alpkokin & Ergun, 2012)
Stombuss (Blue buses) (BRT, Stockholm)	5%	(Finn et al., 2011)
Trans-Val-de-Marne (BRT, Paris)	8%	(Finn et al., 2011)
BRT Line 1 (BRT, Beijing)	12%	(Deng & Nelson, 2013)
Jokeri line (BRT, Helsinki)	12%	(Finn et al., 2011)
TransJakarta (BRT, Jakarta)	14%	(Ernst, 2005)
Bus-VAO (BRT, Madrid)	15%	(Finn et al., 2011)
QBC – Malahide corridor (BRT, Dublin)	17%	(O’Mahony, 2002)
Kent Thameside (BRT, Kent)	19%	(Deng & Nelson, 2011)
Orange Line (BRT, Los Angeles)	19%	(Callaghan & Vincent, 2007)
South Miami-Dade Busway (BRT, Miami)	21%	(National BRT Institute, 2003)
Nantes BHLS (BRT, Nantes)	29%	(Rabuel, 2010)
O-Bahn (BRT, Adelaide)	40%	(Currie & Sarvi, 2012)
Angers Tramway (LRT, Angers)	0%	(Olesen, 2014)
Midland Metro (LRT, Birminigham)	13%	(Harper & Bird, 2000)
Nantes LRT (LRT, Nantes)	17-37%	(Lee & Senior, 2013)
Croydon (LRT, Croydon)	19%	(Copley, Thomas, Maunsell, & Georgeson, 2002)
Metrolink (LRT, Manchester)	21%	(Knowles, 1996)
Blue Line (LRT, Los Angeles)	21%	(Lee & Senior, 2013)
Sheffield Supertram (LRT, Sheffield)	22%	(Lee & Senior, 2013)
Blue Line (LRT, San Diego)	30% ²	(Lee & Senior, 2013)
Orange Line (LRT, San Diego)	50% ²	(Lee & Senior, 2013)
Avg. 14 European systems (LRT)	11%	(Hass-Klau, Crampton, Biereth, & Deutsch, 2003)
Copenhagen Metro (Metro, Copenhagen)	8-14%	(Vuk, 2005)
BART (Metro, San Francisco)	35%	(Richmond, 1991)

Table 1: Mode shift from car traffic for selected public transport systems.

Again, effects vary notably across all systems. However, it should be observed that several of the figures represent relatively small lines. For instance, 22% of the passengers on the Sheffield Supertram were former car users. When comparing with the market share of LRT of 17% the mode shift was only around 4%. This is general for all studies as the numbers represent the percent of passengers who previously travelled by car. In the case of San Diego Trolley 30% of the passengers after the opening of the first line in 1981 were former car users. In 1990 the share was estimated at 50% after the opening of the second line in the same light rail system (Lee & Senior, 2013). Another example worth mentioning was the 19% mode shift obtained for the Los Angeles Orange Line, which was established in a new segregated corridor. A passenger survey showed the same level of satisfaction with the BRT line as with the Gold Line LRT and a higher level of satisfaction than with the Blue Line LRT. This was probably due to the high level of service thanks to the segregated

¹ Percent of passengers who previously travelled by car.

² Mode shift for commuting trips based on travel surveys.

infrastructure (Cain, Flynn, McCourt, & Reyes, 2009). However, the Blue Line also obtained a similarly large mode shift (21%) of passengers from car traffic which in absolute numbers was significantly larger, since the line serves three times as many passengers than the Orange Line. On the other hand, no significant shift from car traffic was obtained for the LRT system in Angers, probably due to the fact that the LRT did not reduce the travel time as compared to the existing bus lines. Instead the LRT was implemented to attach the central urban areas to a high-class public mode of transport (Olesen, 2014).

In general, the findings show that both BRT and LRT systems obtained a sufficiently high attractiveness to attract users from other modes of transport, including former car users. This could indicate that the quality of the upgrade is more important than the choice of system. But as the capacity is often highest for metro systems and lowest for BRT systems a similar mode shift will induce different impacts on car traffic, i.e. metro systems can have larger impacts on road congestion than BRT systems. However, exceptions do exist, e.g. the Metrobús corridor in Istanbul which carries 600,000 passengers per day and hence is running at a very high capacity (Yazici et al., 2013). Hence, in order to obtain notable impacts on car traffic attractive high-capacity systems are needed.

3 Strategic effects

Generally, major improvements to public transport systems will, all other things being equal, result in significant changes in real estate prices (Pagliara & Papa, 2011). Many examples exist of how large infrastructure projects have had a positive influence on urban development, as the accessibility of an area is increased when the transport system is improved resulting in lower travel times. This makes the areas more attractive which is reflected in higher real estate prices for existing buildings, and it also makes the areas more attractive for investors resulting in new urban development. The strategic effects of extending the public transport network may be bigger than the pure traffic effects (Al-Dubiki & Mees, 2010). Many analyses attempt to quantify the effects of real estate prices on various transport systems. Tables 2-4 provide an overview of the influence of BRT, LRT and metro systems on real estate prices.

System	Property value change	Source
BRT Line 1 (Beijing)	0	(Ma et al., 2014)
Seoul BRT (Seoul)	+5-10%	(Cervero & Kang, 2011)
TEOR (Rouen)	+10%	(Martínez & Viegas, 2009)
TransMilenio (Bogotá)	+11-13%	(Perdomo Calvo, Mendoza, Baquero-Ruiz, & Mendieta-Lopez, 2007), (Rodríguez & Targa, 2004)
East Busway (Pittsburgh, USA)	+16%	(V. Perk et al., 2010)
South-East Busway (Brisbane)	+20%	(Levinson, Zimmerman, Clinger, Rutherford, et al., 2003)
Guangzhou BRT (Guangzhou)	+0-30%	(Suzuki, Cervero, & Iuchi, 2013), (Salon et al., 2014)

Table 2: Effects of BRT systems on property values.

System	Property value change	Source
Supertram (Sheffield, UK)	0	(Dabinett, Gore, Haywood, & Lawless, 1999)
Sacramento RT Light Rail (Sacramento, USA)	0	(Landis, Guhathakurta, Huang, Zhang, & Fukuji, 1995)
Metrolink light rail (Manchester, UK)	0	(Martínez & Viegas, 2009)
	-6%	(Forrest, Glen, & Ward, 1996)
MetroRail (Houston, USA)	+/-	(Pan, 2012)
Eastside MAX (Portland, USA)	+0-10.6%	(Al-Mosaind, Dueker, & Strathman, 1993), (Chen, Rufolo, & Dueker, 1998)
San Diego Trolley (San Diego, USA)	+0-17.3%	(Cervero & Duncan, 2002b; Landis et al., 1995)
Buffalo Metro Rail (Buffalo, USA)	+2-5%	(Hess & Almeida, 2007)
Bybanen (LRT, Bergen)	+4%	(Fredriksen, 2013)
DART (Dallas, USA)	+10-25%	(Weinstein & Clower, 2002),
Metro Light Rail (Phoenix, USA)	+25%	(Golub, Guhathakurta, & Sollapuram, 2012)
Metrolink (St. Louis, USA)	+32%	(Martínez & Viegas, 2009)
Tramlink (Croydon, UK)	+	(ATISREAL, Geofutures, UCL, & Group, 2004)
Docklands (London, UK)	+	(Knowles & Ferbrache, 2015; Martínez & Viegas, 2009)

Table 3: Effects of LRT systems on property values. Note: + denotes significant, but non-quantified positive effects, and +/- denotes mixed positive and negative non-quantified effects.

System	Property value change	Source
Coaster (San Diego, USA)	-7.1%	(Cervero & Duncan, 2002b)
Caltrain (San Francisco, USA)	0	(Landis et al., 1995)
Miami metrorail (Miami, USA)	0	(Gatzlaff & Smith, 1993)
MARTA (Atlanta, USA)	+/-	(Bollinger & Ihlanfeldt, 1997)
BART (San Francisco, USA)	+0-4%	(Landis, Zhang, & Guhathakurta, 1994), (Landis et al., 1995), (Dueker & Bianco, 1999)
Lindenwold line (Philadelphia, USA)	+0-8%	(Voith, 1993)
Tyne and Wear Metro (Newcastle, UK)	+2%	(Pickett, 1984)
Copenhagen Metro	+3.8%	(Kolstrup, 2006)
SEPTA (Philadelphia, USA)	+3.8%	(Voith, 1991)
MBTA (Boston, USA)	+6-10%	(J. Armstrong & Robert, 1994)
Belfast suburban rail (Belfast)	+8%	(Adair, McGreal, Smyth, Cooper, & Ryley, 2000)
Helsinki metro (Helsinki)	+8%	(Hack, 2002)
Seoul Subway (Seoul)	+9%	(Bae, Jun, & Park, 2003)
PATCO (Philadelphia, USA)	+10%	(Voith, 1991)
Midway line (Chicago, USA)	+17%	(McDonald & Osuji, 1995)
Metra (Chicago, USA)	+20%	(Lin, 2002)
Toronto subway (Toronto)	+20%	(Hack, 2002)
Jubilee Line Extension (London, UK)	+	(Jones et al., 2004; Martínez & Viegas, 2009)
Guangzhou Metro (Guangzhou)	+	(Salon et al., 2014)

Table 4: Effects of metro and heavy rail systems on property values. Note: + denotes significant, but non-quantified positive effects, and +/- denotes mixed positive and negative non-quantified effects.

There are thus big differences between the listed projects. There are two important factors that are important to highlight before comparing the figures.

Firstly, there is no general standardised method for the calculation of changes in real estate prices (Banister & Thurstain-Goodwin, 2011). Consequently the different studies used a variety of methods of analysis and data sources (Munoz-Raskin, 2010). For example, different distances were used to define when a property was placed close to a station. However, the impact area was considered to be approximately 1000 m for residential properties and 400 m for commercial properties such as shops and offices (Banister & Thurstain-Goodwin, 2011). There was however a high degree of variability since some studies analysed properties within a distance of 200-400 m (Hess & Almeida, 2007) and others examined properties within a distance of 1,000 m (Rodríguez & Mojica, 2009) or just indicated that the property was within an urban area served by a station (R. J. Armstrong & Rodríguez, 2006; Voith, 1993).

Secondly, the projects were very dependent on local conditions (Martínez & Viegas, 2009). This was observed even between corridors within the same study. In San Diego considerably higher sales prices (between 4% and 17%) could be demonstrated for properties within walking distance of a light rail station, depending on the corridor in which the property was situated (Cervero & Duncan, 2002b). In one of the corridors no relationship between price and distance to the station could be found. This was also reflected in a similar study of the effects of various systems in Los Angeles (Cervero & Duncan, 2002a). Here the results varied considerably depending on the type of property (house, flat and commercial property) and station type (bus, metro and light rail). The same result was found in connection with the establishment of the LRT system in Phoenix where the results to a large extent depended on the types of dwellings (Golub et al., 2012). In Philadelphia very different effects were also found for different networks, since real estate prices for properties close to PATCO stations were 10% higher, whereas the prices of properties situated closer to SEPTA stations were only 4% higher than those of comparable properties. However, in this case the difference could be partly explained by other factors, one of them being that PATCO provided better travel times as compared to car and SEPTA (Voith, 1991).

When analysing the impacts on property values further, several findings were observed. For several of the systems the analyses showed that the effects occurred even before the system was implemented. The prices thus increased due to the *expectation* of improved accessibility. This was observed in connection with the establishment of the railway line between Chicago and the Midway Airport where the property prices rose by 17% within a distance of 800 m from the future stations. This observation was made three years before the connection actually opened (McDonald & Osuji, 1995). A similar effect was observed in Seoul where the station distance only affected property values significantly prior to the opening of the line 5 subway (Bae et al., 2003). In Portland land values increased significantly when the construction of the MAX LRT system was announced (Knaap, Ding, & Hopkins, 2001), and they increased even more after the system had been implemented (Chen et al., 1998).

In addition to the projects mentioned in Tables 2-4 there are many other examples of projects where a general significant tendency of decreasing real estate prices can be observed when the distance to the nearest station increases. However, this tendency is not found for all distances. In particular, several studies found a direct negative effect within a very short distance from the station (Brandt & Maennig, 2011; Chen et al., 1998; Debrezion, Pels, & Rietveld, 2006; Landis et al., 1994). This was explained by increased noise annoyances and, to some extent, higher crime rates. In Phoenix this relationship was analysed explicitly since shorter distances to light rail stations resulted in higher real estate prices, whereas shorter distances to the light rail alignment resulted in lower real estate prices (Golub et al., 2012). Similarly, in Houston close proximity to LRT stations had significant negative impacts on property values whereas positive effects were seen for properties located longer away from stations (Pan, 2012). In Chen et al. (1998) the relative influence of the negative nuisance effects and the positive improved accessibility effects for the Portland MAX LRT system was compared. It was found that the improved accessibility outweighed the nuisance effects, but the study highlighted the importance of taking into account the nuisance effects which vary depending on the type of public transport system.

Such effects have also been observed for BRT systems. In Guangzhou real estate prices within 1,000 m from the BRT stations decreased whereas they increased for properties more than 1,000 m away from the stations. This tendency was not found for metro stations and was to a large extent due to noise annoyances and congestion problems (Salon et al., 2014). However, for the TransMilenio in Bogotá such an effect was not found (Munoz-Raskin, 2010). Here higher real estate prices were observed within a distance of 250 m from a BRT station than in a 250-500 m band around the stations.

Several of the examined BRT systems have shown to have a relatively large impact on property values with increases of up to 20-30% in Brisbane in Australia. This large increase followed a significant upgrade where a completely segregated bus lane was established in a corridor from the city centre to the university southeast of the city which resulted in a reduction of the travel time by more than 30% (Currie, 2006a). In the time following the opening of the system real estate prices in the corridor rose 2-3 times faster than those of similar properties, and the prices of residential properties within walking distance from the bus corridor were 20% higher after the opening than those of other comparable properties (Levinson, Zimmerman, Clinger, & Gast, 2003). Bogotá also saw an increase of 13-15% for residential properties situated within 1,000 m of the TransMilenio system after the opening of an extension of the network (Rodríguez & Mojica, 2009). A minor effect was observed in Seoul where the price of residential properties within 300 m from the new BRT line rose by 5-10% after the opening of the line (Cervero & Kang, 2011). According to the same study the price of commercial properties within 150 m from a station rose by up to 26%. In Pittsburgh (V. Perk et al., 2010) found that the East Busway BRT had a significant positive effect on real estate prices, and the effect of being close to a BRT station was bigger than that of being close to an LRT station.

Other studies have compared the effects of BRT, LRT and metro, respectively. Debrezion, Pels, & Rietveld (2007) concluded that real estate prices of properties situated within 400 m from so-called commuter rail stations were 14.1% higher, based on a comparison of 73 local public transport systems. However, no significant differences were found for properties situated close to LRT and BRT stations. In addition, the same study found that the effect on real estate prices was bigger for commercial properties than for residential properties when the property was situated within 400 m from a station. On the other hand, the effect was higher for residential properties situated more than 400 m from the station. In Beijing the effects of the newly established BRT line, Line 1, were compared with the effects of the metro (Ma et al., 2014). Here it was found that real estate prices were 5% higher for properties close to metro stations (within 800 m), whereas no significant effect for properties situated close to BRT stations could be found. However, Deng & Nelson (2013) report that the BRT line had positive effects on property development including rising property values along its corridor. This was based on a survey distributed to real-estate agents. In Guangzhou a minor effect for properties situated close to BRT stations could be observed, but it was not nearly as big as the effect observed for properties near the metro (Salon et al., 2014). This could be both because the metro was more attractive, and also because the station areas around the metro had more attractive shops and were perceived as being less influenced by externalities, e.g. noise and congestion. Generally, the largest effects were found for the lines providing the biggest travel time benefits.

There is also a tendency that the effect was biggest in low-income areas whereas high-income areas did not experience the same increase in property values (Salon et al., 2014). This was probably because the inhabitants of these areas did not use public transport to the same extent as the low-income groups where car ownership was generally lower. This, however, was not unequivocal as the opposite effect could be observed in Buffalo, USA (Hess and Almeida, 2007). Here the high-income areas experienced a positive effect from the light rail system whereas the low-income areas experienced a negative effect.

A number of studies found decreasing real estate prices after the implementation of rail systems. In Manchester the proximity effect was -6% which was probably due to an average distance to stations within the entire area of analysis of only 1.36 km. Hence, many residents already had access to stations (Forrest et al., 1996). Similarly, a decrease of 7% was found in San Diego which was explained by a very low ridership in a corridor with generally very high average incomes. Thus, the residents in the corridor did not find the system attractive (Cervero & Duncan, 2002b). In Atlanta, up to 19% lower real estate prices were found within 400 m of MARTA stations. On the other hand, the prices were highest in a 1-3 mile band around the stations, probably because the negative externalities in the form of noise and crime close to the stations had a higher impact than the attractiveness of the system (Bowes & Ihlanfeldt, 2001).

An overview of the magnitudes of impacts on property values of BRT, LRT and metros is shown as a histogram in Figure 2. Note, however, that the graph only shows selected results from Tables 2-4 since many studies only concluded whether or not a significant effect could be observed.

As a consequence, the histogram only includes 41 of the 86 systems reviewed. Furthermore, as mentioned many big differences generally exist between the projects. A conclusion based directly on the histogram would imply a significant degree of uncertainty.

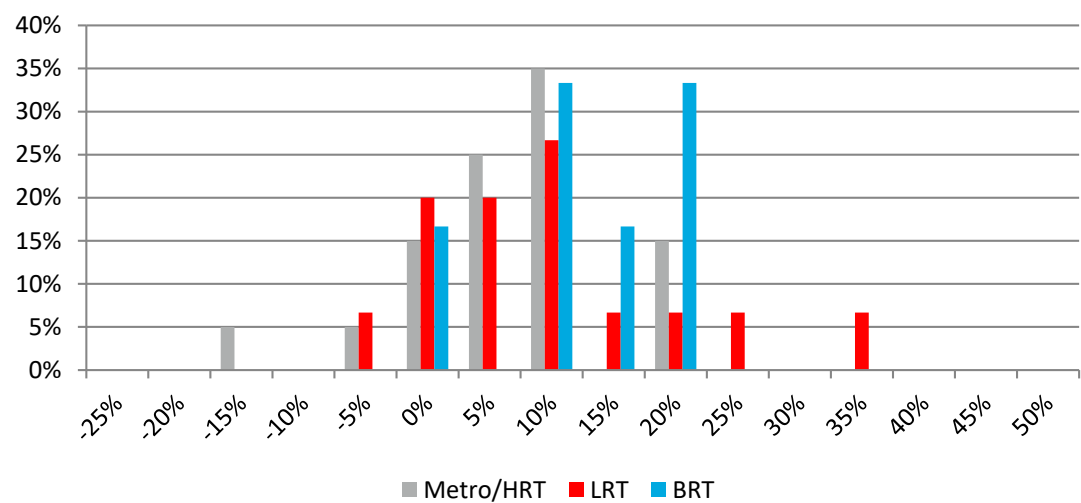


Figure 2: Change in property values after implementation of public transport systems.

The distributions of the changes in property values were tested using two-sample t-tests across the three modes, i.e. BRT, LRT, and metro/heavy rail. The three subsamples showed no significant differences between variances, hence the pooled test statistic was preferred.

System	DF	t value	Pr > t
Metro vs. LRT	33	0.89	0.3811
Metro vs. BRT	24	1.41	0.1719
LRT vs. BRT	19	0.61	0.5509

Table 5: Statistical t-tests of the difference in means of property value effects across public transport modes.

Generally, the results showed no significant differences across the three modes, i.e. significant strategic effects in terms of increases in property values were not limited to rail-based public transport systems, cf. Table 5. Projects that resulted in big increases in property values, as well as projects with less or no influence, were found across all three modes. Based on the subsample of projects in this study there seems to be a more certain difference between BRT and metro/heavy rail projects (83% confidence level) whereas the least certain difference is seen when comparing LRT and BRT (45% confidence level). Hence, the present study finds the largest effects for BRT systems and the lowest effects for metro/heavy rail, cf. Figure 2. However, the effects for all systems are significantly positive, and not significantly different from each other. Hence, based on these simple key figures it is not possible to draw any general conclusions about the influence of each of the three transport systems on the real estate market. Instead, the findings suggest that effects are rather due to other reasons than the choice of type of system. Most importantly, large effects were observed when notable improvements were implemented. In addition, negative effects were seen close to station areas due to externalities which highlights the importance of creating attractive station areas when implementing public transport systems. Thorough implementation is thus important in ensuring positive effects on property values.

4 Urban development

As could be seen in the previous section, increases in real estate prices are not exclusively associated with rail-based public transport systems. It should therefore be possible to obtain urban development effects in relation to BRT. However, there are not many examples of urban development in connection with BRT in Europe and Asia reported in the literature (Cervero, 2013; Deng & Nelson, 2011). Several studies argue that some of the reasons for this are the lack of permanence (Dittmar & Ohland, 2004; Parker, McKeever, Arrington, & Smith-Heimer, 2002; Rodríguez & Targa, 2004) and lack of newness (Parker et al., 2002) of bus-based systems as compared to rail-based systems. However, a review of possible reasons in (Currie, 2006b) showed that the largest weaknesses were related to weak industry capabilities regarding bus-based transit-oriented development (TOD), the lack of a positive track record for already implemented systems and the availability of park-and-ride facilities as they limit TOD opportunities (Currie, 2006a). In (Kamruzzaman, Baker, Washington, & Turrell, 2014) a comparison of different types of TOD in Brisbane was conducted which confirmed well-known effects of increased transit ridership and the use of active travel modes for people living in TODs. These results were found for both bus-based and rail-based TOD, hence suggesting that effects are not mode-specific, but rather a result of coherent planning.

The best examples of urban development in corridors served by buses are probably Curitiba and Ottawa (Currie, 2006b). In Curitiba, the BRT system became a big success, since 45% of the longer trips which were not made by foot or bicycle, were made by the BRT system (Cervero & Dai, 2014). The urban development was assured by means of planning laws that dictated that urban development should take place along the BRT corridors (Cervero, 1998). Hence, the system was not only implemented as a tool to improve the traffic situation in the city, but rather also as an instrument to form the urban development in a more sustainable direction. In Ottawa, a significant urban development was also seen in connection with the implementation of the BRT system Transitway. Due to the big success of the system, the urban development was concentrated along the bus lines, and the largest economic effect was precisely the urban development which was assessed to be worth about \$675 million (Levinson, Zimmerman, Clinger, Rutherford, et al., 2003). Almost the same high investment level was obtained as a result of the BRT line in Pittsburgh where renovations and new constructions worth about \$302 million were carried out in connection with the stations along the East Busway (Levinson, Zimmerman, Clinger, & Gast, 2003). Similar trends were seen in Boston where properties near the BRT line were densified after the implementation of the Silver Line BRT. The properties were to a great extent converted into apartment buildings. The total amount of money put into the urban development reached more than \$600 million (V. A. Perk, Catala, & Reader, 2012). Even larger effects were observed along the Euclid Corridor transportation project in Cleveland totalling \$4.3 billion in real-estate developments (Weinstock et al., 2011). The Orange Line in Los Angeles also gave rise to urban development near the stations due to the significantly improved travel time and the generally high attractiveness of the system after the opening (Callaghan & Vincent,

2007). Furthermore, a certain urban development was obtained in connection with the BRT line in Seoul (Cervero & Kang, 2011). Here the areas around the BRT stations were developed, and a densification of the dwellings from one-family houses to flats was seen. It was assessed that notably improved travel times and regularity were more important parameters for a potential urban development than the type of system which was implemented. This suggested that urban developments could be obtained by both BRT and rail-based systems if urban development was integrated into the planning of station areas as early as possible in the planning process (Levinson et al., 2002).

Other BRT systems did not obtain the same effects. In Adelaide, no evidence of increased urban development was seen in relation to the O-Bahn system (Currie, 2006a). One important reason was that more than 50% of boarding passengers used car as access mode hence requiring large park-and-ride facilities at station areas which restricts the urban development potential (Dittmar & Ohland, 2004). Similarly, in Ahmedabad in India and Bogotá in Columbia no significant effect on urban development was observed despite the fact that TransMilenio in Bogotá is one the world's most advanced BRT with a large extension and high ridership (Cervero & Dai, 2014). For these two cities the main reason was assessed to be bad station conditions. During the construction phase focus was on creating a cost-effective and fast system which was out of tune with the development of the station areas. Many stations were placed in the middle of large roads to ensure the highest possible travel speed at the lowest possible price. This resulted in bad accessibility for pedestrians and unattractive station areas. This is underpinned by other analyses from Bogotá which showed that attributes such as pavements and zebra crossings were highly valued by the passengers of the system. Hence, stations with easy access had significantly more passengers than other stations (Estupiñán & Rodríguez, 2008). Furthermore, Cervero et al. (2004) emphasised that good pedestrian access is crucial for ensuring successful TOD. It is therefore important to bear these considerations in mind during the planning phase of public transport projects. This is especially important for BRT systems where the challenge with respect to creating the potential for urban development at stations is bigger than for metros which do not create externalities at the surface level due to them being underground systems.

5 Discussion

While the current study provides a thorough review of the existing literature and compares the effects of various modes of public transport, the data source used in this study is not without limitations.

Firstly, the study compiled a large sample of 86 public transport systems. Though it is comprehensive and of a sufficient size to not being random data, it is not complete as it for obvious reasons does not include all systems ever implemented. Neither is it fully representative in terms of systems from specific countries, city sizes, etc. Hence, future work could focus on investigating the impacts from transit systems as a function of local economic or demographic characteristics as well as

the actual level of service improvements, effects on ridership, changes in mode choice and property values.

Secondly, the data were collected from numerous different sources which applied different methodologies hence giving rise to lacking consistency. For studies on traffic impacts the reported improvements were measured at different time points after completion or implementation of the systems. Hence, ridership increases and modal shifts were not directly comparable between studies. The systems included in this study all reported effects obtained after up to 3-4 years after completion in order to reduce the effect of general traffic growth or other factors. Some studies were deliberately not included as they reported effects after up to 10 years after completion.

The inconsistency also applied to the studies on property values. As previously mentioned different definitions of station proximity were used, but studies also used different methodological approaches when estimating the station proximity impact. Most studies used the hedonic pricing method, but studies differed in estimation methods with only some studies taking into account spatial autocorrelation, e.g. Rodríguez & Targa (2004). Other studies reported changes in property values based on comparisons with control group areas, e.g. V. Perk & Catalá (2009), Salon et al. (2014), Weinstein & Clower (2002), and others.

For the urban development effects no consistent definition exists of what impacts to include among urban regeneration, development projects, TOD or densification of existing properties. Hence, the present paper summarises findings from numerous papers on this topic with the purpose of highlighting possible effects rather than creating specific comparisons between transport modes. Further research could investigate the link between urban development effects and the public transport systems in more detail, including the most important elements contributing to an improved level of service and urban development, a research area also highlighted by other studies, e.g. in Stokenberga (2014).

Thirdly, this paper operates with a division into three groups of transit systems, namely BRT, LRT and metro/commuter rail systems. While many systems are easily classified, others are more difficult to classify. This is especially the case for many improved bus systems incorporating scattered bus lanes and single ITS features. However, in order to being able to analyse strategic effects this paper has only included BRT systems that are notably upgraded from conventional bus lines in terms of (almost) fully segregated infrastructure and multiple ITS elements. Similar definition challenges exist for rail lines. For example the Metrolink network in Manchester was upgraded from an existing suburban, heavy rail system into a LRT system by adding newly constructed lines on city centre streets with stations in the downtown area (Forrest et al., 1996; Knowles, 1996). Hence, parts of the system could be categorised as commuter rail even after the transformation of the network. In the present paper this system was categorised as LRT. The LRT systems included vary with regards to the degree of segregation from other traffic, as many otherwise successful LRT systems are mixed with car traffic, especially in narrow city centre street networks. The last group of systems include commuter rail and metro systems which are characterised by being heavy rail systems running at

higher speeds with longer stop spacings. The final division into three groups was a compromise between creating as few groups as possible while at the same time ensuring their homogeneity. Hence, a division into more groups could be reasonable; for example by further dividing BRT systems based on the BRT level as suggested by Wright & Hook (2007), splitting LRT and traditional tram systems, possibly taking into account the degree of segregation from other traffic, or creating independent groups for heavy rail dependent on whether they are underground or overground systems or dependent on train type used, e.g. large regional trains or small metro trains. However, a further division of systems would reduce the sample size for each system.

Lastly, this study did not focus on whether effects on property values are in fact generative. Several sources question this suggesting that effects are rather distributive (Handy, 2005). By this, the positive effects should not be seen as pure growth, but rather as a redistribution of growth in the area close to the new public transport system which is outweighed by the decreasing property values in other areas (Giuliano, 2004). However, even if impacts are redistributive, Cervero (2009) suggests that a total positive effect is realised because of the agglomeration effects occurring from the spatial redistribution, thus creating generative economic growth. Further research should investigate this aspect in greater detail in order to draw conclusions on this aspect.

6 Conclusions

This present paper showed that large effects on travel time can occur by implementing BRT and lead to significant modal shifts similar to those found when implementing rail-based public transport systems such as LRT and metro. In addition, the review of 86 public transport systems showed that significant positive impacts on property values can be obtained by investing in public transport systems independent of system choice, i.e. BRT, LRT or metro/heavy rail. For the 41 projects which were analysed statistically in this study no significant differences between system choices were found, but BRT systems seemed to show the largest effects. The results suggested that the impacts depend more on the extent to which the system improves the existing situation, the competition with car traffic and how the system is implemented in the local context.

For BRT systems, notable improvements with respect to travel times compared to the basis situation are needed in order for people to consider the system as being more attractive than ordinary bus lines. This also includes measures to improve the overall travel time, e.g. service frequency, and comfort, e.g. guidance. Furthermore, it is important to ensure good accessibility to the station areas to obtain positive strategic effects in the form of urban development and increased property values. However, it can be difficult to combine short travel times and improved urban spaces, as high-class BRT systems take up large areas at the surface level as compared to underground metro systems. The largest travel time reductions and increases in ridership were thus seen in cities where the BRT line was segregated from other traffic, for instance in the middle of a large road, and where operations were frequent thus reducing waiting times. Such system designs make it difficult to create attractive

urban spaces around BRT stations due to the significant intervention in the urban space as compared to the establishment of for instance sub-surface metro systems. This was confirmed by several analyses that showed decreasing real estate prices in the immediate vicinity of BRT stations as the benefits from the increased mobility did not compensate for the negative externalities, e.g. noise and barrier effects. To create successful BRT systems it is thus essential to consider how to obtain large benefits in the form of travel time and improved accessibility while at the same time creating an attractive and accessible environment around the stations.

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